X-ray Magnetic Linear Dichroism of Fe-Ni Alloys on Cu(111)

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INTRODUCTION

We are studying layer-by-layer synthesis of ultra-thin metal films by controlling at the monolayer level the composition and structure of these films, including the interfacial region. We have prepared Fe_xNi_{1-x} multilayers using simultaneous evaporation of pure Ni and Fe on Cu(111) in order to better understand the Giant Magnetoresistance (GMR) effect in NiFe/Cu systems that are relevant to magnetic disk drive heads. Using Undulator Beamline 7.0 and the Spin Spectroscopy Facility (7.0.1.2) at the ALS, we have measured X-ray Magnetic Linear Dichroism (XMLD) signals for fourteen different thin Ni-Fe alloys films on Cu(111) for different thicknesses and with Fe concentration ranging from 9% to 84%. X-ray Photoelectron Spectroscopy (XPS) with 1250 eV photon energy was utilized to determine both thickness and elemental composition. The Fe3p and Ni3p lines were measured for magnetization up and down, and the difference is the XMLD signal. Our XMLD spectra clearly indicate that samples of specific thicknesses and Fe concentrations are ferromagnetic. XMLD has previously been used to characterize Fe_xNi_{1-x} alloy fcc multilayers on Cu(100).[1] On Cu(111), high Fe asymmetry was found for Fe concentration less than or equal to 60% which is followed by a transition to low asymmetry at higher Fe concentrations accompanied by a new low-spin ferromagnetic phase.[2]

RESULTS

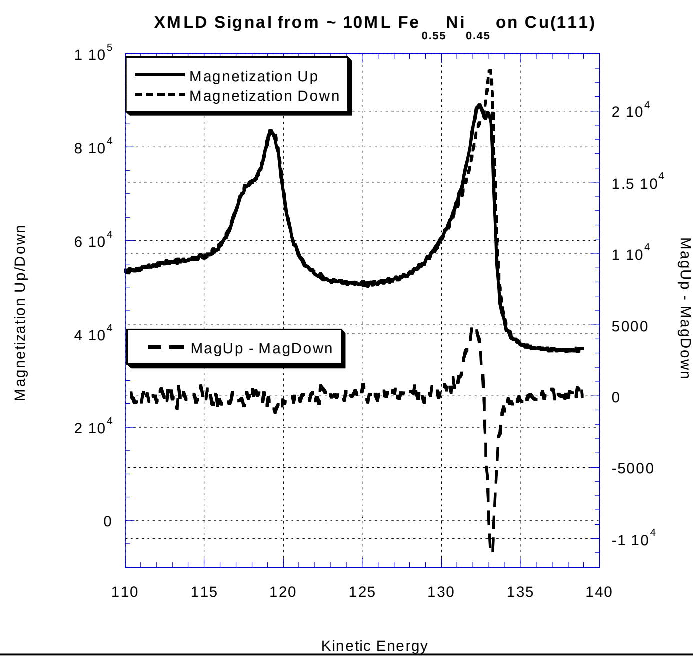

Fig. 1. XMLD data from $Fe_{0.55}Ni_{0.45}$ thin film, 10ML thick, on Cu(111). Top of figure shows the signal for both magnetization up and down. Bottom of figure shows difference, which is proportion to the dichroism.

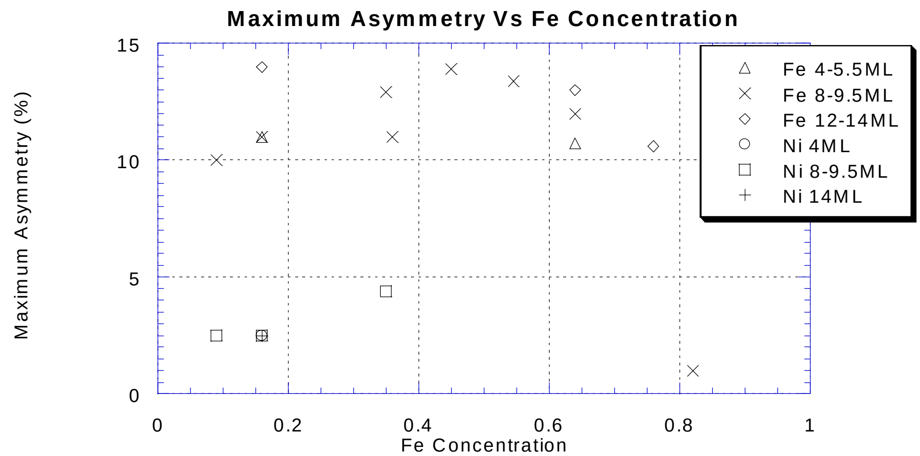

Fig. 2. Maximum measured asymmetry of Fe and Ni, as a function of Fe concentration, for three different thicknesses of films on Cu(111).

Figure 1 shows the XMLD effect for Fe concentration of 0.55 and thickness of 10 ML. The upper panel clearly shows that the XPS data are different depending on the orientation of the applied field relative to the sample. The lower panel shows the difference between the two spectra in the upper panel and exhibits the dichroism effect. We have examined the size of the dichroism signal as a function of both composition and film thickness, as shown in the following figures. We have also measured the dichroism signal from both the Fe and the Ni peaks.

The asymmetry, $\dfrac{\text{MagUp - MagDown}}{\text{MagUp + MagDown}}$, as measured from the XMLD signal, is proportional to the total magnetization of the sample. Figure 2 shows how the maximum Fe and Ni asymmetries changes with concentration for 3 different film thicknesses. As the concentration x of Fe increases, the maximum asymmetry increases until x≈0.6 (near the Invar transition) and then decreases.

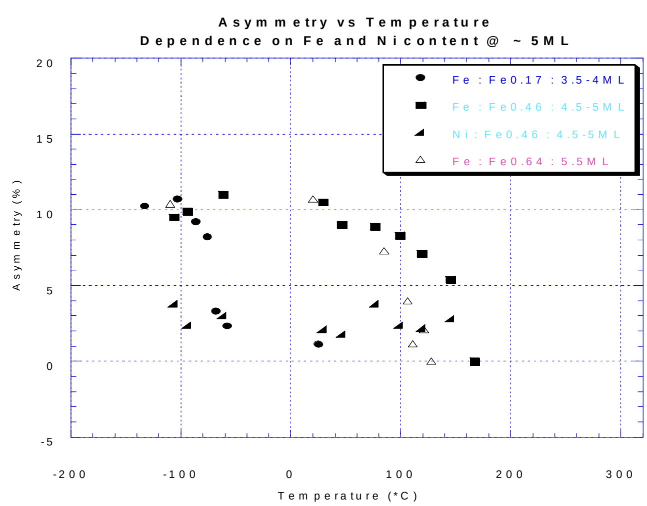

Fig. 3. Fe and Ni asymmetry as a function of temperature, for three Fe concentrations and film thicknesses near 5ML.

Figure 3 shows the asymmetry as a function of temperature for films with three different Fe concentrations, all ~5ML thick. Although the data appear to fit the predictions from mean field theory, detailed fits to the theory are still in progress. With increasing Fe concentration, the Curie temperature, where the asymmetry disappears, increases until x≈0.6, and then decreases.

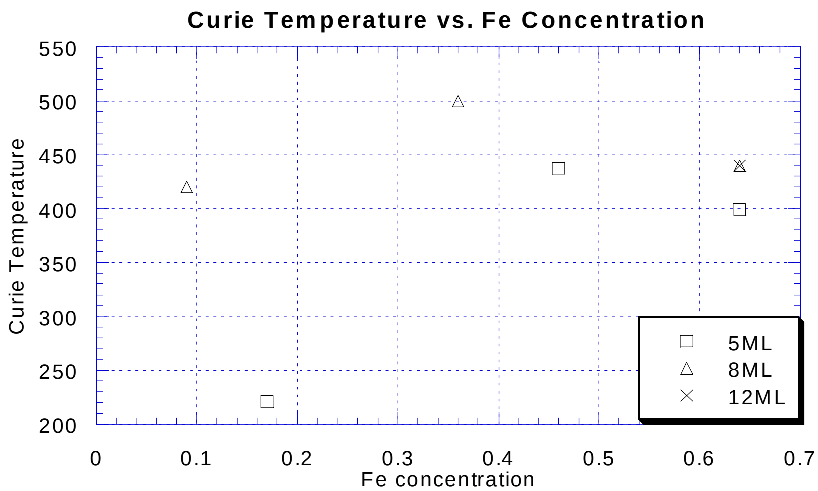

Fig. 4. Approximate Curie temperature as a function of Fe concentration, for three different film thicknesses. Note the maximum Curie temperature curve occurs near x=0.4.

An approximate Curie temperature (T_c) for the ferromagnetic samples was extracted by extrapolating data, such as those in Figure 3, to find the temperature at which the magnetic asymmetry disappears. Figure 4 illustrates the change in Curie temperature for varying thickness and concentration. As could be seen in the data in Figure 3, as the Fe concentration increases, T_c increases until x≈0.4 and then decreases. For all of our samples, T_c was in the range from 200K to 500K.

Work is in progress to compare these data with previously published XMLD results for FeNi thin films on Cu(100) substrates.[1] The data are also being compared with previously published SQUID measurements for FeNi films on Cu(111) to perform an absolute calibration of the XMLD signal.[2]

REFERENCES

1. Schumann, Willis, Goodman, Tobin, PRL, 79, 5166 (1997)
2. Freeland, Grigorov, Walker, Phys. Rev. B, 57, 80 (1998)

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